(NASA-CR-123638) REPORT, STATUS, MASS PROPERTIES FOR PHASE A/B STUDY FOR A PRESSURE FED ENGINE ON A REUSABLE SPACE SHUTTLE BOOSTER (Aerojet Liquid Rocket Co.) 15 Mar. 1972 26 p CSCL 21H G3/28

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REPORT, STATUS, MASS PROPERTIES

FOR

PHASE A/B STUDY FOR A PRESSURE FED ENGINE ON A REUSABLE SPACE SHUTTLE BOOSTER

NASA - MSFC - REPORT NO. SE-019-014-2H

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
George C. Marshall Space Flight Center
Huntsville, Alabama 35812

Contract NAS 8-28217
DPD 303; DR SE-03

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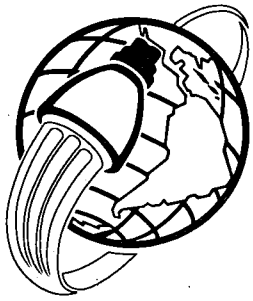

AEROJET LIQUID ROCKET COMPANY
A DIVISION OF AEROJET-GENERAL
SACRAMENTO, CALIFORNIA

FOREWORD

This Mass Properties Report is prepared in accordance with the applicable requirements of MIL-M-38310A issue dated 15 July 1966, title: Mass Properties Control Requirements for Missile and Space Vehicles as specified in Data Requirement Document No. 303.

These data are presented in accordance with the Data Procurement Document (DPD) No. 303, dated October 1971, which specifies the Data Requirement (DR) No. SE-03 for Contract NAS 8-28217.

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FIGURE LIST

Figure No.	Title
1	Engine Assembly
2	Interface-Pressure-Fed Booster
3	Combustion Chamber Weight vs Chamber Surface Area
4	Thrust Chamber Nozzle Weight vs Nozzle Surface Area
5	Injector Weight vs Injector Diameter
6	Valve Weight vs Diameter
7	Total Propellant Line Weights vs Sea-Level Thrust
8	Gimbal Bearing Weight vs Vacuum Thrust

I. REVIEW FOR MANAGEMENT

This document contains the engine weight, mass properties data, and engine design criteria and specifications for a 1.2 million-lb sea-level thrust pressure-fed LOX/RP-1 engine. Engine trade study weight data are also presented herein.

The current engine weights are compared to previously reported weight data and are summarized below.

	Weights, lb		
	Previous	Current	Change
Total Engine Dry	17484	17640	+156
Total Wet Burnout	21344	21880	+536
Total Wet Operating	25964	26500	+536

II. DESIGN DATA STATEMENT

Engine Sea-Level Thrust, lb	1,200,000
Engine Vacuum Thrust, lb	1,462,000
Number of Engines per Vehicle	7
Propellants	LOX/RP-1
Materials	Materials are listed on Component Drawings: See SE-019-012-2H and SE-019-009-2H
Type of Propellant Feed	Pressure-Fed
Type of Construction	See Component Drawings
Type of Cooling - Combustion Chamber	Regenerative (RP-1)
- Nozzle	Regenerative (RP-1)
Number of Starts, Minimum	40
Mission Burn Time, sec	150
Throttling Ratio	70% of Rated Chamber Pressure
Expansion Ratio	5:1
Characteristic Exhaust Velocity, ft/sec	5691
Mixture Ratio	2.4
Ignition Type	Hypergol
Specific Impulse - Sea-Level, sec	237.8
Specific Impulse - Vacuum, sec	289.8
Thrust Coefficient - Sea-Level	1.3445
Thrust Coefficient - Vacuum	1.6381
Throat Area, $in.^2$	3570
Exit Area, $in.^2$	17850
Thrust Chamber Pressure, psia	250
Total Propellant Flowrate, lb/sec	5046.3
Fuel Flowrate, lb/sec	1484.2
Oxidizer Flowrate, lb/sec	3562.1
Fuel Inlet Pressure, psia	380

II, Design Data Statement (cont.)

Oxidizer Inlet Pressure, psia	380
Fuel Inlet Temperature, °R	537
Oxidizer Inlet Temperature, °R	163
Injector Type	Modular
Injector Thrust per Element	∿ 1000
Injection Element Type	Like-on-Like
Combustion Chamber Length, in.	70
Chamber Contraction Ratio	1.8
Nozzle Contour Length	86% Bell
Thrust Vector Control Method	Head-End Gimbal with Bellows in Articulating Lines
Thrust Vector Control Angle	± 6°
Valve Type	Right Angle Poppet
Fuel Propellant Line Velocity, ft/sec	15
Oxidizer Propellant Line Velocity, ft/sec	25
Engine Fuel Inlet Line Diameter, in.	19
Engine Oxidizer Inlet Line Diameter, in.	19
Fuel Valve Inlet Diameter, in.	13.5
Oxidizer Valve Inlet Diameter, in.	13.5
Structural Criteria	MSFC-HDBK-505
Material Properties and Design Allowances	MIL-HDBK-5

III. DATA SOURCES AND CONFIGURATION DRAWINGS

The primary data sources for the current weights and mass properties are the drawings listed below. Detail weights were calculated for the dimensions and materials shown on the component drawings.

Title	Drawing No.
Engine Assembly	1162106
Interface Pressure-Fed Booster	1162107
Thrust Chamber	1162101
Thrust Chamber Details	1162086
Injector Assembly	1162100
Thrust Chamber Assembly	1162104
Igniter and Control Schematic	1162099
Valve Assembly	1162085
Gimbal Assembly	1162108

The engine assembly layout drawing is shown on Figure 1 and the engine interface drawing, Figure 2, shows the engine reference axes. Center of gravity and moment of inertia data is referenced to the gimbal point.

The above component drawings not included herein are presented in Report Numbers SE-019-012-2H, "Package, Preliminary Design Data" and SE-019-009-2H, "Report, Final, Phase A/B Study" Volume B submitted under this contract. A preliminary Interface Control Document (ICD) and Contract End Item (CEI) Specification is also contained in SE-019-012-2H.

The base weights (targets) were based on geometric scaling of components used on existing liquid rocket designs. The historical engine component weight data is presented in Figures 3 through 8.

IV. SUMMARY WEIGHT STATEMENT

Code	Description	Specified Weight Base (Previous) lb	Revised Specified Weight Base	Current Weight, lb	Changes Last to Current lb	Percentage Breakdown of Current Weight Est	Calc	Act	Note Number
5.1	Engine, Dry	17484		17640	+ 156		100		
5.1.1	Combustion Chamber	3519		4227	+ 708		100		
5.1.2	Nozzle	4800		3542	-1258		100		
5.1.3	Injector	4752		4788	+ 36		100		
5.1.4	Valves	1546		2420	+ 874		100		
5.1.5	Propellant Lines	1212		1137	- 75		100		
5.1.6	Gimbal Block	596		467	- 129		100		
5.1.7	Miscellaneous	1059		1059	0	100			
5.2	Engine, Wet Operating	25964		26500	+ 536		100		
5.3	Engine, Wet Burnout	21344		21880	+ 536		100		
21.0	Propellants	8480		8860	+ 380		100		

V. DETAIL WEIGHT STATEMENT

Code	Description	Weight, lb Code Generation First	Second	Third
5.1	Engine, Dry	17640		
5.1.1	Combustion Chamber		4227	
5.1.1.1	Flange and Fuel Inlet Manifold			1160
5.1.1.2	Support Structure (Can)			920
5.1.1.3	Wire Wrap			695
5.1.1.4	Wire Attaching Rings			446
5.1.1.5	Tubes			853
5.1.1.6	Braze Material			107
5.1.1.7	Weld Material			46
5.1.2	Nozzle		3542	
5.1.2.1	Tubes			2327
5.1.2.2	Turn Around Manifold			9
5.1.2.3	Stiffening Rings			790
5.1.2.4	Braze Material			291
5.1.2.5	Weld Material			125
5.1.3	Injector		4788	
5.1.3.1	Injector Module Housing and Flange			2290
5.1.3.2	Modules (Total of 55)			2110
5.1.3.3	Manifolding and Gimbal Support			388

V, Detail Weight Statement (cont.)

Code	Description	Weight, lb Code Generation First	Second	Third
5.1.4	Valves		2420	
5.1.4.1	Fuel Valves (Total of 2)			1210
5.1.4.2	Oxidizer Valves (Total of 2)			1210
5.1.5	Propellant Lines		1137	
5.1.5.1	Fuel Lines			615
5.1.5.2	Oxidizer Lines			522
5.1.6	Gimbal Block		467	
5.1.7	Miscellaneous		1059	
5.1.7.1	Gimbal Actuator Supports			184
5.1.7.2	Propellant Line Supports			255
5.1.7.3	Controller			21
5.1.7.4	Electrical Harness			67
5.1.7.5	Ignition System			35
5.1.7.6	Instrumentation and Bosses			17
5.1.7.7	Purge Valves and Plumbing			140
5.1.7.8	Interface Panel			150
5.1.7.9	Valve Actuation System			190

V, Detail Weight Statement (cont.)

Code	Description	Weight, lb Code Generation First	Second	Third
5.2	Engine, Wet Operating		26500	
5.3	Engine, Wet Burnout (Oxidizer Depletion)		21880	
21.0	Propellants	8860		
21.3	Fuel		4240	
21.3.1	19" Engine Inlet Lines			1823
21.3.2	13.5" Lines at Valves			912
21.3.4	Manifolding			325
21.3.5	Coolant Jacket			1180
21.4	Oxidizer		4620	
21.4.1	19" Engine Inlet Lines			2810
21.4.2	13.5" Lines at Valves			595
21.4.3	Oxidizer Dome and Manifolding			1215

VI. SEQUENCED MASS PROPERTIES STATEMENT

Code	Description	Current Weight lb	Center of Gravity (Inches from Ref. Datum) X	Y	Z	Moment of Inertia (Slug-ft^2) Pitch	Roll	Yaw	Note Number
5.1	Engine, Dry	17640	66.			41000		41000	1, 2
5.2	Engine, Wet Operating	26500	60			43150		43150	3
5.3	Engine, Wet Burnout	21880							4

1 Reference Datum is Gimbal Point (See Figure 2).

2 Pre-Launch, Prefill Engine Weight.

3 Engine Weight with all Lines, Manifolding and Coolant Jacket full of Propellant.

4 Engine Weight with only the Fuel Lines, Manifolding and Coolant Jacket full of Propellant. Oxidizer is entirely depleted.

VII. SUMMARY MASS PROPERTIES STATEMENT

Code	Description	Current Weight lb	Center of Gravity (Inches from Ref. Datum) X	Y	Z	Moment of Inertia (Slug-ft^2) Pitch	Roll	Yaw
5.1	Engine, Dry	17640	66			41000		41000
5.1.1	Combustion Chamber	4227						
5.1.2	Nozzle	3542						
5.1.3	Injector	4788						
5.1.4	Valves	2420						
5.1.5	Propellant Lines	1137						
5.1.6	Gimbal Block	467						
5.1.7	Miscellaneous	1059						
5.2	Engine, Wet Operating	26500	60			43150		43150
5.3	Engine, Wet Burnout	21880						
21.0	Propellants	8860						

VIII. CHANGE ANALYSIS AND IMPROVEMENT POTENTIALS

The current engine weights are compared to last previously reported weights in the table below.

Code	Description	Weights, lb Previous	Current	Changes
5.1	Engine, Dry	17484	17640	+ 156
5.1.1	Combustion Chamber	3519	4227	+ 708
5.1.2	Nozzle	4800	3542	-1258
5.1.3	Injector	4752	4788	+ 36
5.1.4	Valves	1546	2420	+ 874
5.1.5	Lines	1212	1137	- 75
5.1.6	Gimbal Block	596	467	- 129
5.1.7	Miscellaneous	1059	1059	0
5.2	Engine, Wet Operating	25964	26500	+ 536
5.3	Engine, Wet Burnout (1)	21344	21880	+ 536
21.0	Propellants			
21.3	Fuel	3860	4240	+ 380
21.4	Oxidizer	4620	4620	0

This above comparison shows some changes in component dry weights, but no major overall change in the total engine dry weight. The major reason for the component weight changes is that a different method was used to obtain the current weight estimates. The current weights are based upon calculations using component engineering drawings. On the other hand, the previous component base weights (targets) were established by geometric scaling of existing engine data. The change in the engine wet weights resulted from a recalculation of the trapped propellant volumes.

(1) Assumes oxidizer depletion.

VIII, Change Analysis and Improvement Potentials (cont.)

Because the component drawings represent preliminary type designs, further changes can be expected. Future emphasis would be placed upon detailed engine and component design analyses to reduce component weights.

IX. UNRESOLVED PROBLEMS

None.

X. TRADE STUDY DATA

Parametric engine weights were generated to provide input to vehicle contractor studies and to optimize the engine design. These parametric values were generated by geometric scaling of weight data for existing engine components as illustrated in Figures 3 through 8. The scaling was accomplished by a FORTRAN program of mathematical scaling relationships run on a UNIVAC 1108 computer. Typical output data is shown on Page 13. Figures 3 through 8 also compare the existing engine component data, data obtained from the scaling relationships and the current pressure-fed engine component weights. Although engine component weights vary from those scaled, the total engine weight data obtained from scaling relationships is valid.

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PRESSURE FED BOOSTER ENGINE

THRUST					
SEA LEVEL, NOMINAL	600000.0	800000.0	1000000.0	1200000.0	1400000.0
VACUUM, NOMINAL	731197.5	974930.0	1218662.5	1462395.0	1706127.5
SPECIFIC IMPULSE					
SEA LEVEL, NOMINAL	237.8	237.8	237.8	237.8	237.8
SEA LEVEL, MINIMUM	235.8	235.8	235.8	235.8	235.8
VACUUM, NOMINAL	289.8	289.8	289.8	289.8	289.8
VACUUM, MINIMUM	287.3	287.3	287.3	287.3	287.3
FLOWRATE					
TOTAL	2523.1	3364.2	4205.2	5046.3	5887.3
OXIDIZER	1781.0	2374.7	2968.4	3562.1	4155.7
FUEL	742.1	989.5	1236.8	1484.2	1731.6
MIXTURE RATIO	2.4	2.4	2.4	2.4	2.4
ENGINE					
LENGTH, IN.	200.7	220.9	238.8	254.9	269.7
OUTSIDE DIA, IN.	108.6	125.1	139.6	152.6	164.8
DRY WEIGHT, LB.	8587.8	11447.8	14414.3	17483.6	20651.1
WET WEIGHT, LB.	10027.8	13614.2	17390.6	21343.6	25461.7
COMBUSTION CHAMBER					
PRESSURE, PSIA	250.0	250.0	250.0	250.0	250.0
FACE PRESSURE	277.0	277.0	277.0	277.0	277.0
CHAR. VELOCITY C*	5690.6	5690.6	5690.6	5690.6	5690.6
LENGTH, IN.	70.0	70.0	70.0	70.0	70.0
CONTRACTION RATIO	1.8	1.8	1.8	1.8	1.8
THROAT AREA, SQ. IN.	1785.0	2380.0	2975.0	3570.0	4165.0
THROAT DIAMETER, IN.	47.7	55.0	61.5	67.4	72.8
DRY WEIGHT, LB.	2471.5	2860.2	3204.9	3518.5	3808.7
THRUST CHAMBER NOZZLE					
AREA RATIO	5.0	5.0	5.0	5.0	5.0
PERCENT BELL	86.0	86.0	86.0	86.0	86.0
LENGTH, IN.	94.6	109.2	122.1	133.7	144.4
INSIDE DIA, IN.	106.6	123.1	137.6	150.8	162.8
DRY WEIGHT, LB.	2400.2	3200.3	4000.4	4800.5	5600.6
INJECTOR					
INSIDE DIA, IN.	64.0	73.9	82.6	90.5	97.7
LENGTH, IN.	7.0	8.1	9.0	9.9	10.6
DRY WEIGHT, LB.	1680.0	2586.5	3614.8	4751.7	5987.9
MAIN FUEL VALVE					
DRY WEIGHT, LB.	303.1	447.0	604.1	772.7	951.5
MAIN OX. VALVE					
DRY WEIGHT, LB.	303.1	447.0	604.1	772.7	951.5
PROPELLANT LINES					
DRY WEIGHT, LB.	649.8	841.8	1029.0	1212.5	1393.0
SECONDARY FLUID INJECTION					
ANGLE	6.0	6.0	6.0	6.0	6.0
SPECIFIC IMPULSE	.0	.0	.0	.0	.0
DRY WEIGHT, LB.	.0	.0	.0	.0	.0
GIMBAL OR HINGE BEARINGS					
LENGTH, IN.	29.2	33.7	37.7	41.3	44.6
DRY WEIGHT, LB.	250.5	359.0	474.5	595.9	722.5
GIMBAL ACTUATOR SYSTEM					
ANGLE	6.0	6.0	6.0	6.0	6.0
DRY WEIGHT, LB.	.0	.0	.0	.0	.0
MISCELLANEOUS					
DRY WEIGHT, LB.	529.5	706.0	882.5	1059.0	1235.5

(1) PROPELLANTS - LOX/RP-1
(2) HEAD-END GIMBAL
(3) REGEN COOLED
(4) WEIGHTS DO NOT INCLUDE GIMBAL ACTUATOR OR HYDRAULIC SYSTEM

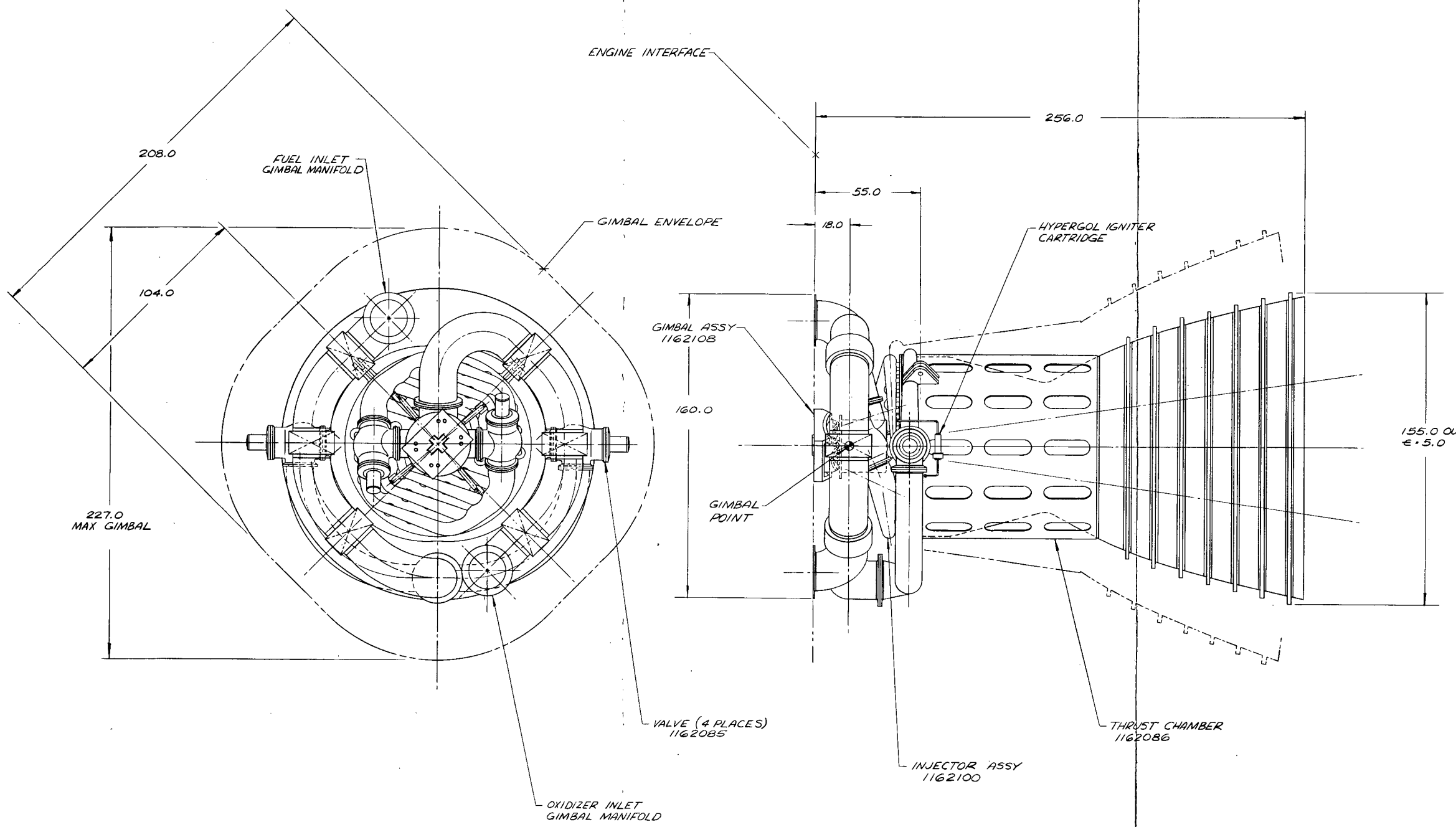

Figure 1. Engine Assembly (D/N 1162106)

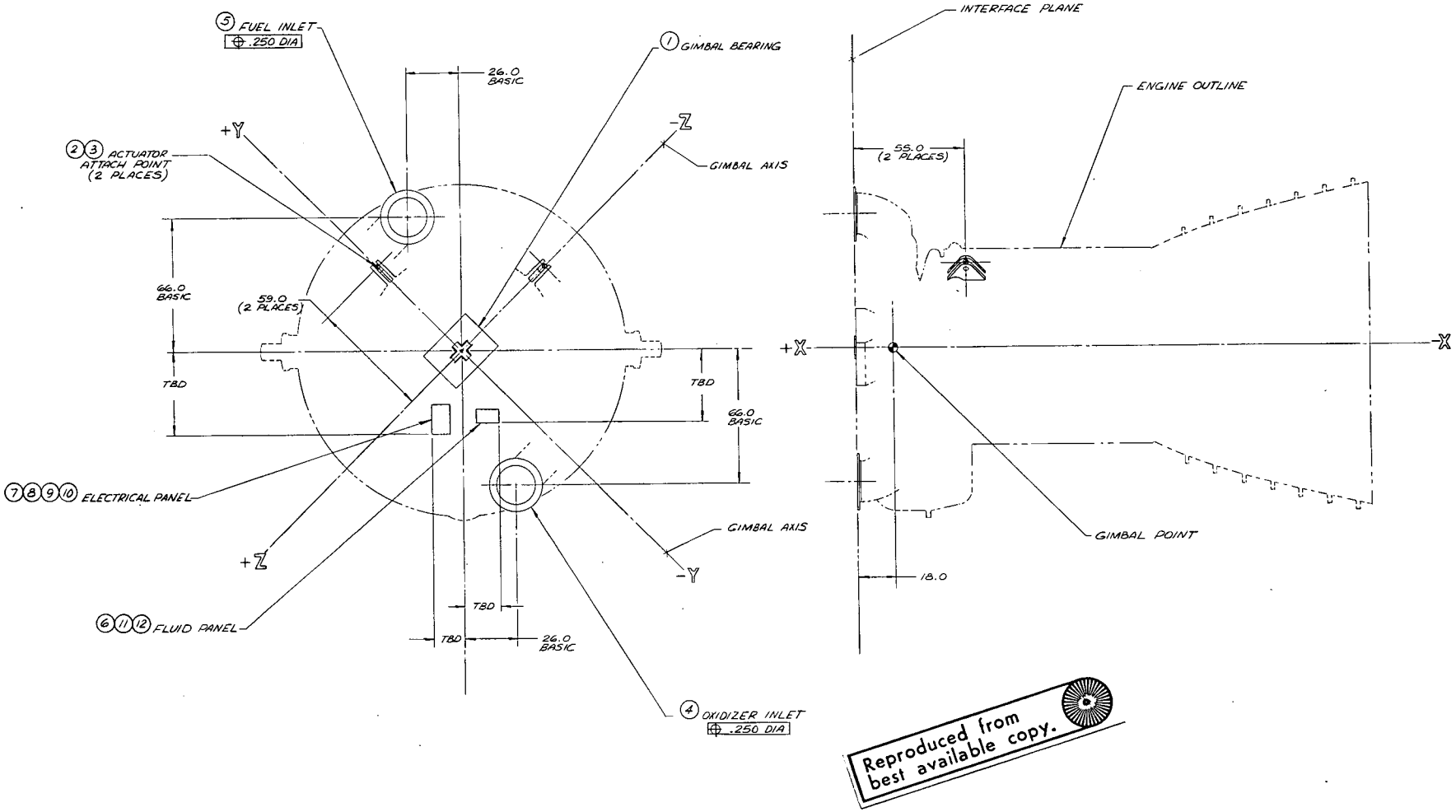

Figure 2

Engine/Vehicle Interface (D/N 1162107)

COMBUSTION CHAMBER WEIGHT vs CHAMBER SURFACE AREA
REGEN COOLED CHAMBER

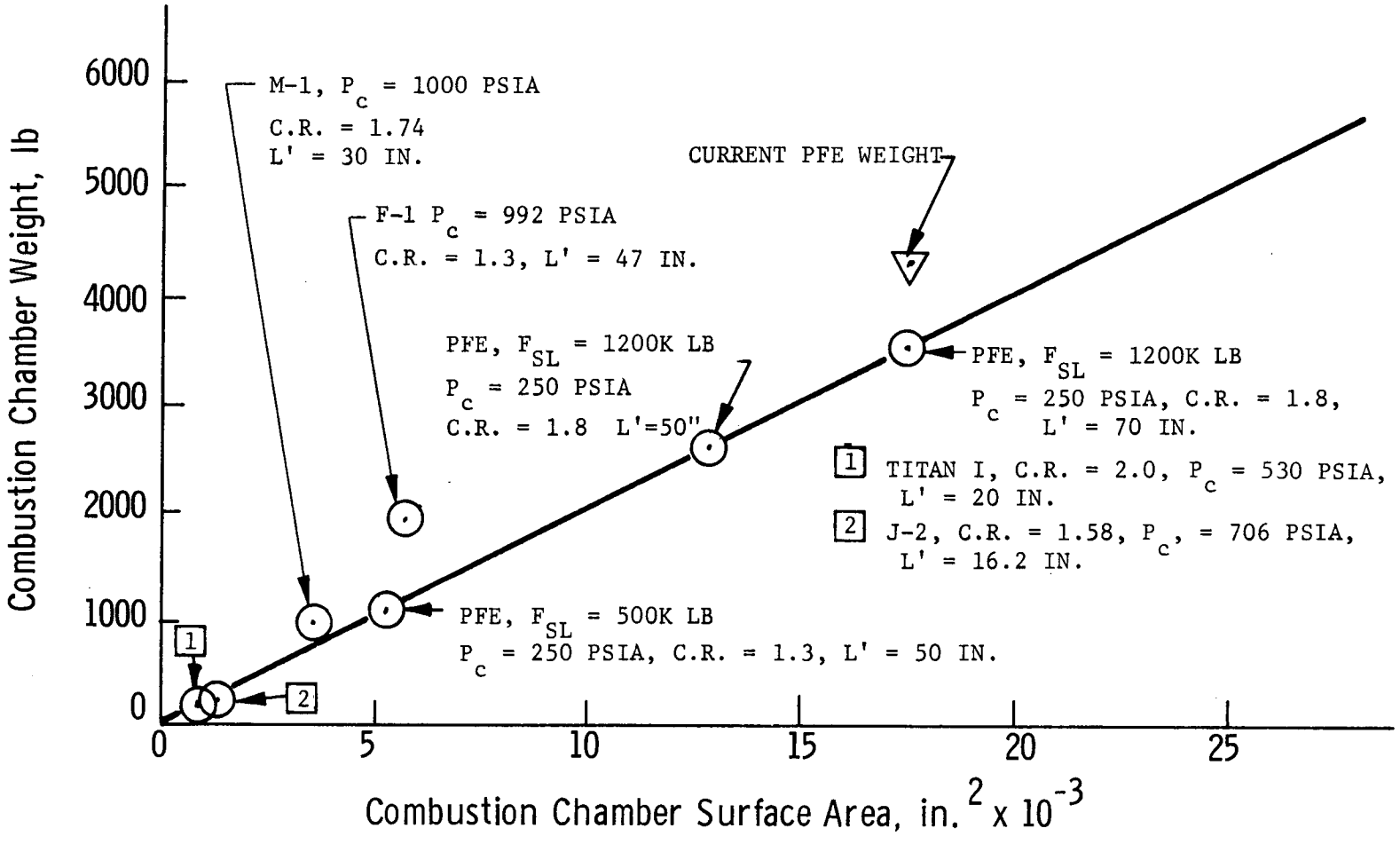

Figure 3

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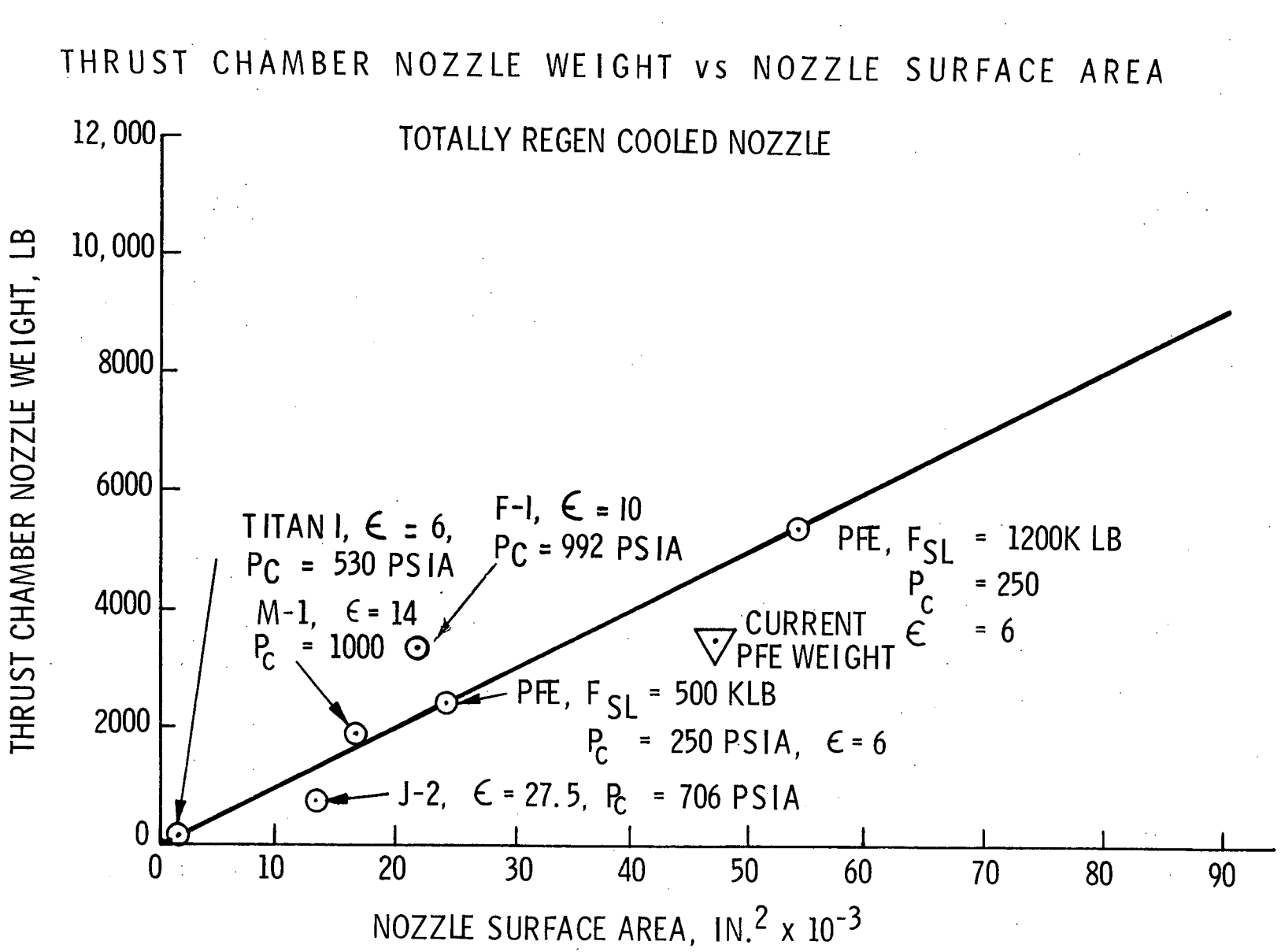

Figure 4

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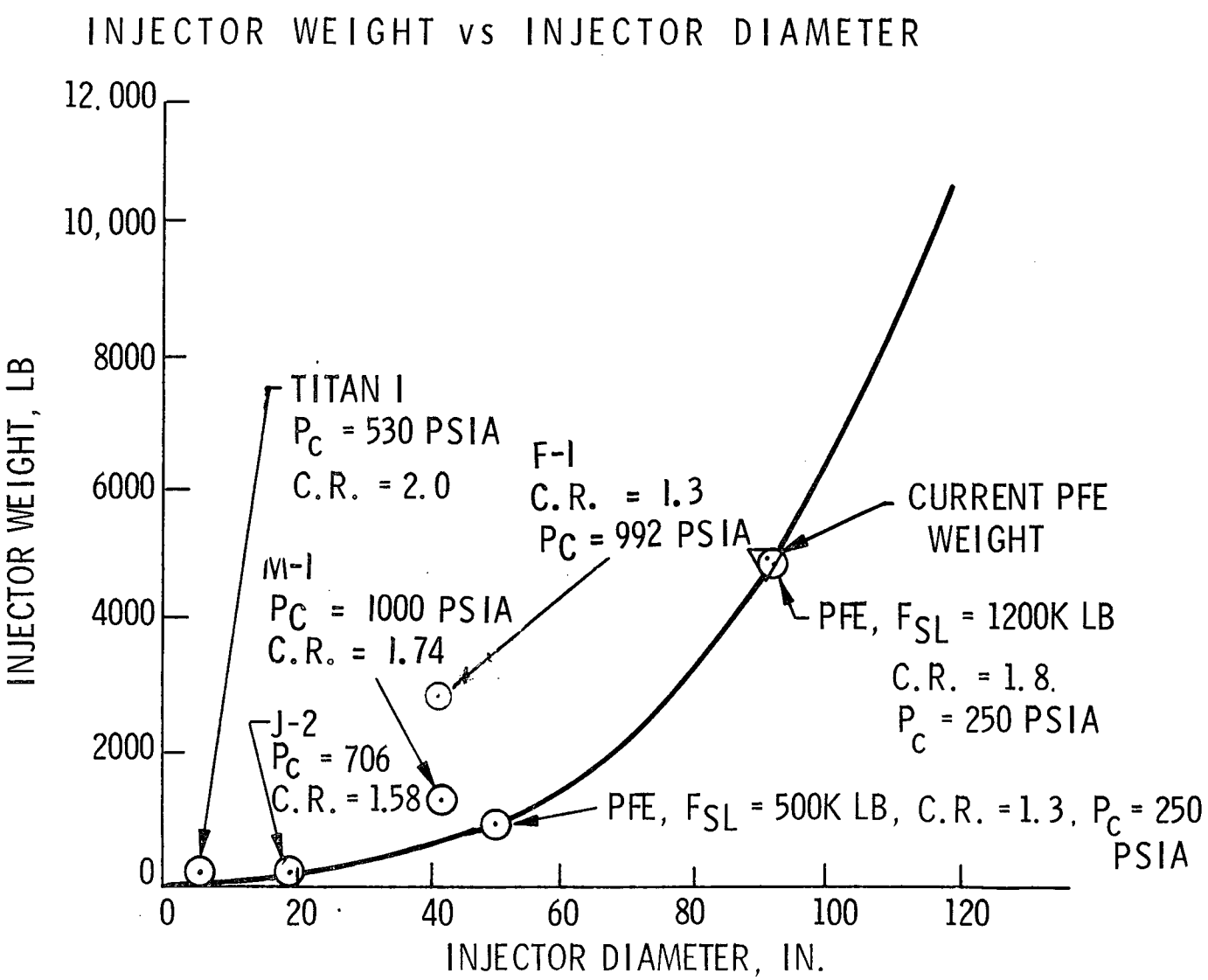

Figure 5

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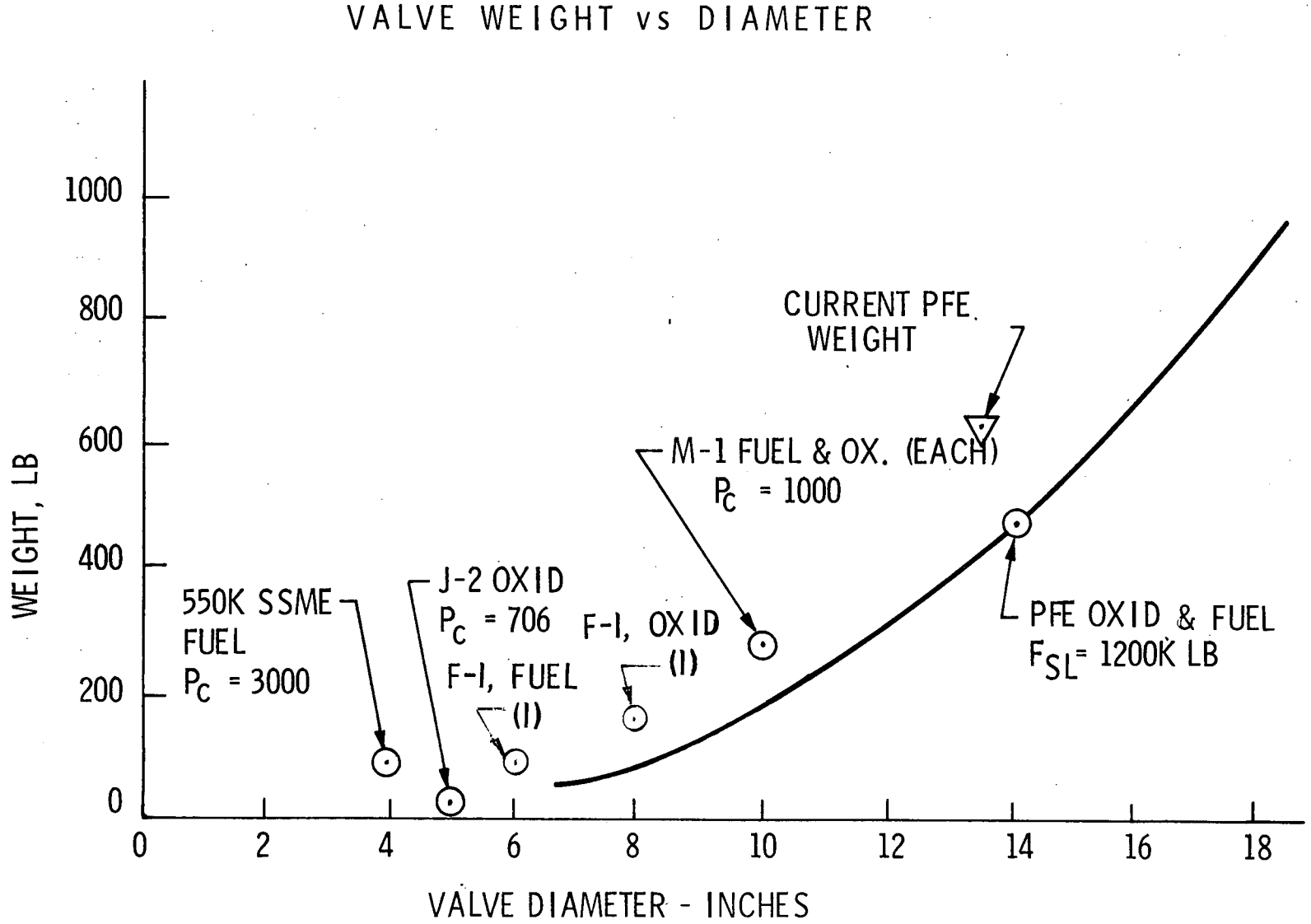

Figure 6

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TOTAL PROPELLANT LINE WEIGHTS VS SEA-LEVEL THRUST LOX/RP-1
(LOW PRESSURE INLET LINES)

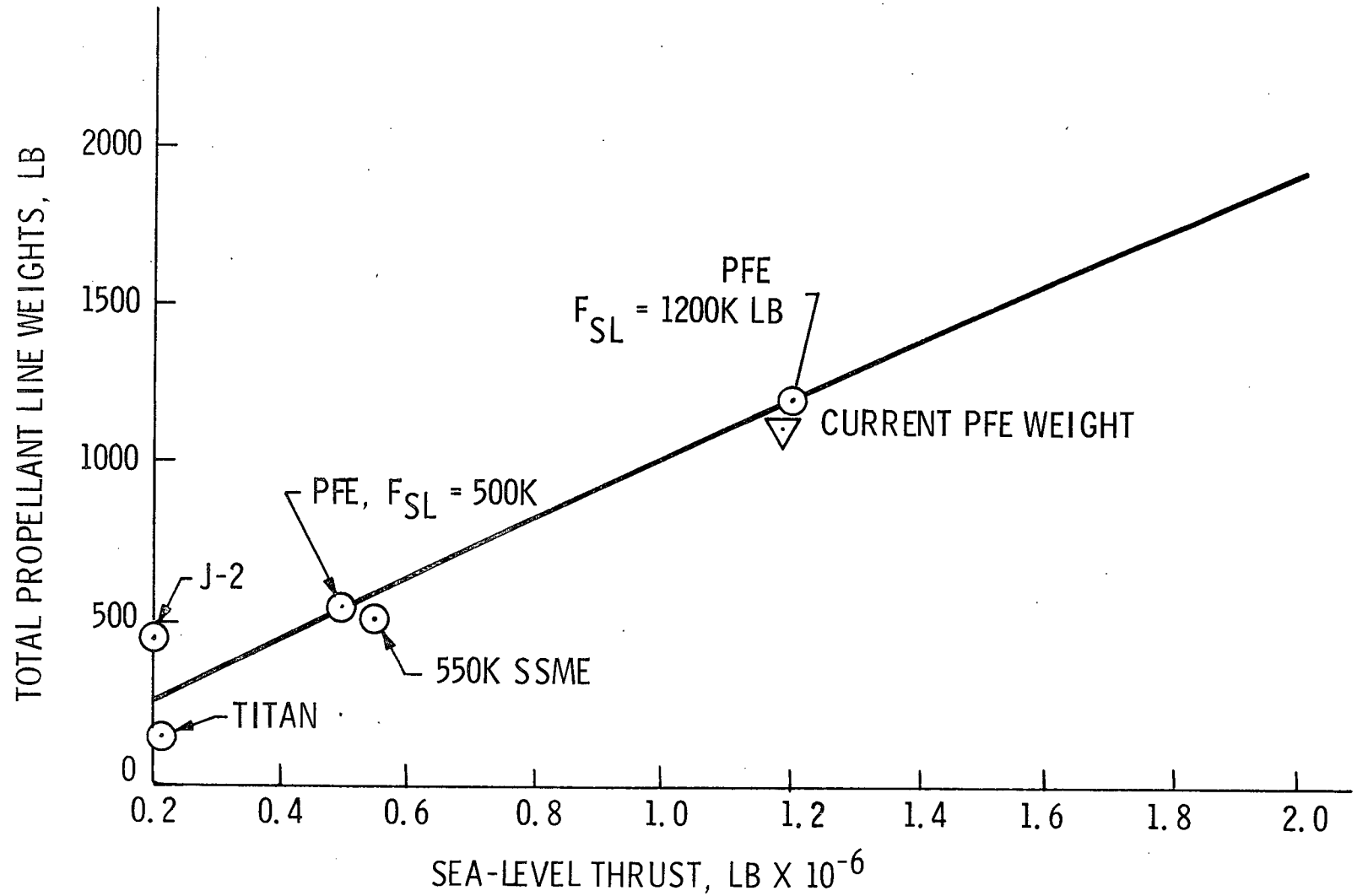

Figure 7

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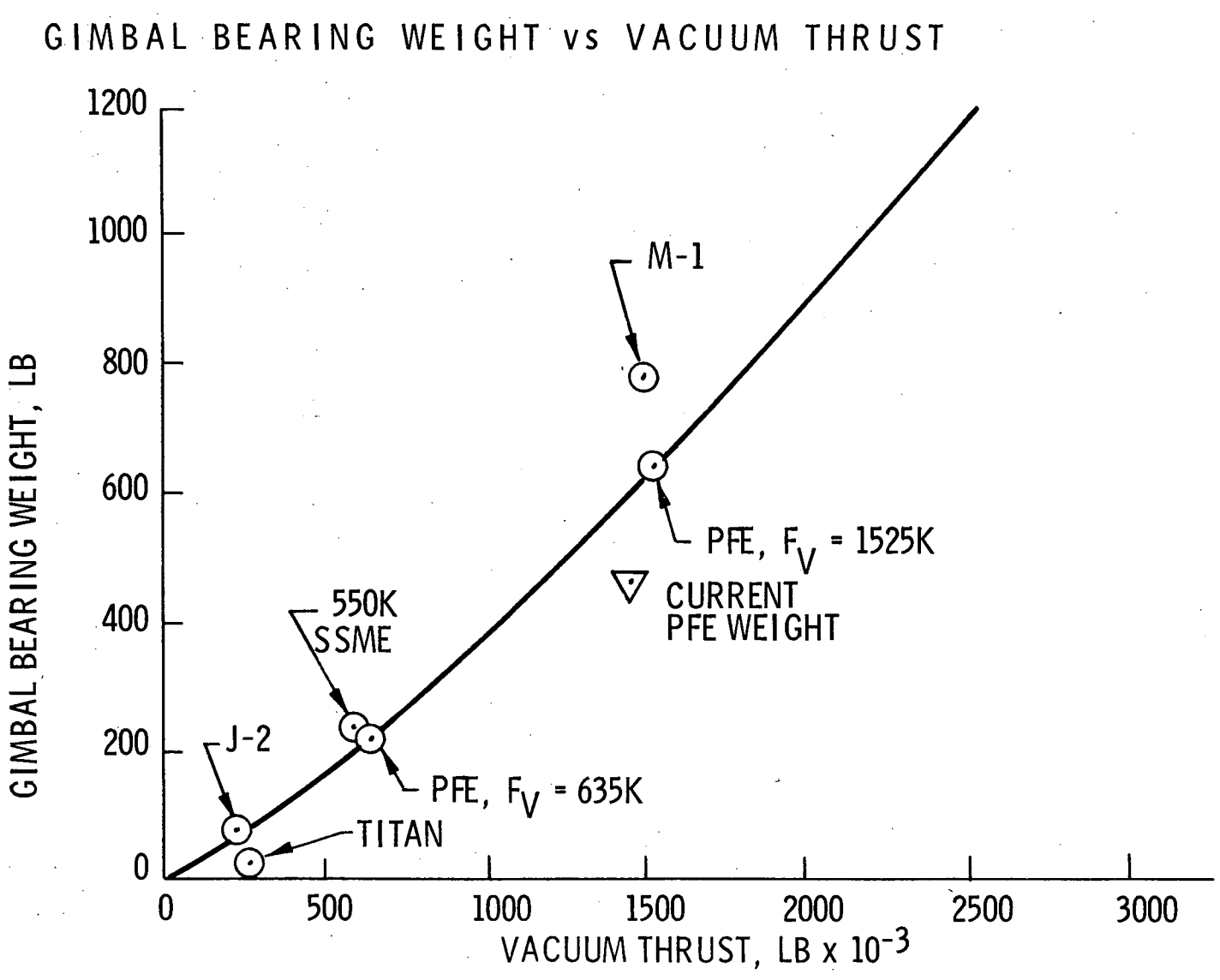

Figure 8

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